ACTIVITY REPORT

March 2002

Natural Gas & Oil Technology Partnership

bringing department of energy national laboratories capabilities to the petroleum industry

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Note: Natural Gas and Oil Technology Partnership projects are reported according to the following schedule:

January, March, May, July, September, November	**February, April, June, August, October, December**
Oil and Gas Recovery Technology	Upstream Environmental Technology
Drilling, Completion, and Stimulation Technology	Downstream Environmental Technology
Diagnostic and Imaging Technology	Ultra-Clean Fuels Technology

Natural Gas and Oil Technology Partnership on the World Wide Web: http://www.sandia.gov/ngotp/

Oil and Gas Recovery Technology

Improved Waterflooding Through Control of Brine Composition and Other Factors

(BP Amoco, U of Wyoming, and INEEL)

Work at the University of Wyoming indicates that crude oil high in wax content may be more amenable than other crudes to increased oil recovery by injecting fresh water during waterflooding. The Monument Butte field in the Uinta Basin, UT, produces a high wax content crude oil. It is the location of an expanding waterflood pilot. Inland Resources, Inc., operators of the field, and project participants provided access to reservoir fluids and reservoir core for laboratory experimentation to determine the applicability of dilute waterflooding to the Monument Butte field to increase oil recovery during waterflood operations.

The Monument Butte field is a topographic and structural trough encompassing an area of more than 9300 square miles. More than 450 million barrels of oil were produced from the Green River and Colton Formations in the Uinta Basin. Other fields in the Basin include the Cedar Rim, Altamont, Bluebell, and Red Wash fields.

Laboratory waterfloods were completed at the reservoir temperature of 140°F. The pour point of this high wax crude oil is about 95°F. INEEL prepared two Berea sandstone core plugs with permeability of 130 md to be used as preliminary tests prior to working with the field cores. The connate water in both cores was the simulated reservoir brine (TDS = 11,780 ppm). Waterflooding with fresh water recovered 7.7% more oil compared to using reservoir brine as the displacing fluid. Oil recoveries were 35.3% of original oil in place (OOIP) for fresh water injection and 32.8% of OOIP for reservoir water injection.

Waterfloods using cleaned plugs cut from field core were also completed to determine the efficacy of diluted waterfloods on field cores. The field cores were considerably tighter than the Berea sandstone, with gas permeabilities of 24.4 md and 28.1 md. Oil recovery using reservoir brine as the displacement fluid was 38.2% OOIP, while the recovery from the fresh water injection was 42.1% OOIP—a differential increase of 10.2%. This is a significant finding, but should be tempered because this is the result of only two corefloods. However, if the results hold true with additional testing, field operators of the Monument Butte field can use these results to aid them as the waterflood is expanded to other parts of the field.

Recent work at the University of Wyoming clarified the dependence of increased recovery from fresh waterflooding on the presence of kaolinite. Experiments using different blocks of Berea sandstone, each with differing quantities of kaolinite, has yielded different results. Waterfloods using the higher kaolinite rock show a much greater response to fresh waterflooding than the waterfloods using lower kaolinite rock.

Fluid Identification Acoustic Logging Tool

(BP Amoco, CGG, ChevronTexaco, Conoco, Landmark Graphics, Schlumberger, Shell, Smedvig Unocal, Ward Petroleum, Western Atlas, and LANL)

Highlight:

- Plans begun to modestly upgrade well-simulator to handle non-volatile hydrocarbons.

The relationships between bubble resonance and bubble motion through fluid, and host liquid properties, such as surface tension, density, and viscosity were studied to obtain a better idea of the volume fraction of gas in a multiphase system. The new measurement method of gas volume fraction is based on both gas volume resonance and motion through the liquid. Since these factors depend on the host liquid properties, it is important to understand the nature of the dependency so that any errors in the measurement can be corrected.

Researchers were unable to gain access to an industrial multi-phase well

simulator for testing of the flow-through measurement logging-tool subassembly. Consequently, the project well simulator will be modestly upgraded to handle non-volatile hydrocarbons. Researchers are now determining requirements for conducting such tests in the simulator, and preparing specifications for components that must be replaced in the simulator in order to conduct the tests.

Measuring Sucker Rod Pump Parameters Downhole (Harbison-Fischer, UT-Austin, and SNL)

Highlight:

- Traveling valve pressure transducer installed.

A crossover between the cable to the surface and the prototype downhole compression chamber pressure transducer is being fabricated. Plans are being made to install this prototype in a test well at Texas Tech.

A traveling valve pressure transducer was installed in the clear-instrumented sucker-rod pump at the University of Texas. Previously, the pressure drop across the traveling valve was measured by pressure transducers on the compression chamber above and below the traveling valve.

Formation Logging Tools for Microboreholes (DeepLook, ChevronTexaco, and LANL)

No work was scheduled for this reporting period.

Coupled Geomechanical Deformation, Fluid Flow, and Seismic Modeling (Mobil, Schlumberger, UT-Austin, and SNL)

Highlight:

- Modifications made to JAS3D to read the initial fluid flow material properties from the IPARS flow simulator.

Modifications were made to JAS3D to read the initial fluid flow material properties from the IPARS flow simulator. This modification will provide the potential for spatially varying porosity and permeability fields to be treated in JAS3D without duplicating information already available in IPARS. Simple problems with varying porosity and permeability were modeled to validate these changes. A more complex problem involving more than 20 wells is in preparation.

Semiautomatic System for Waterflood Surveillance (ChevronTexaco, Case Services, and LBNL)

Highlight:

- Subsidence rates evaluated.

The data files with injection pressure-injection rates records from several injectors on low-permeability reservoir (diatomite) were transferred to LBNL. The data were analyzed using a new well test analysis method developed at LBNL. The analysis suggests the possible presence of relatively high-permeable zones developed by rock damage. The results were discussed with the field engineers during a meeting held in Lost Hills, CA.

The data received by an LBNL computer were preprocessed for controller input. Therefore, the preprocessing module was successfully tested. Based on the acquired data, calibration of fracture diagnostics module of the controller is in progress.

Analysis of Satellite Images and Rock Damage Assessment

Pattern-by-pattern evaluation of subsidence rates was performed. A software utility visualizing and evaluating the subsidence satellite measurements in an arbitrary region of the field was developed.

Mechanisms of Oil Recovery and Validation of Corefloods

(ChevronTexaco, Phillips, and LBNL)

Highlights:

- New scaling obtained for phase conductance of three-phase flow in angular pores.
- Object-oriented algorithm of extraction of the pore network skeleton from a digital micro-image developed.

New scaling was obtained for phase conductance of three-phase flow in angular pores. The new scaling was verified against high-accuracy numerical calculations based on finite-elements methods for numerous combinations of contact angles and boundary conditions at fluid-rock and fluid-fluid interfaces. The deviation of the scaled conductances obtained from numerical results is two to four times less than analogous results reported in the literature.

Pore Network Generation

An object-oriented algorithm of extraction of the pore network skeleton from a digital micro-image was developed. The algorithm was implemented in C++ code, and tested on synthetic and real 3D micro-images of porous structures.

Statistical analysis of thin sections was continued. Different correlations functions were tested based on their ability to characterize rock properties.

Direct Simulation of Near-Wellbore Mechanics

(ChevronTexaco, Halliburton, Schlumberger Shell, MIT, NMT, and SNL)

Highlight:

- Researchers introduced new boundary conditions to the 2D code and prototyped the 3D code.

The amended project cooperative research and development agreement to bring Schlumberger on board as an industry participant was approved by the DOE and three of the four industry participants (researchers are still awaiting Shell's execution of this agreement). The research collaboration with the geo-hydrology group at New Mexico Tech (NMT) progressed with the hiring of an NMT doctoral student to begin beta-testing and later applying codes to study fluid-induced fracture initiation. Current work is focused on the introduction of new boundary conditions to the 2D code and the prototyping of the 3D code.

Publications

Cook et al. "Discrete Element Modeling Applied to Laboratory Simulation of Near-Wellbore Mechanics," Accepted for publication in the *International Journal of Geomechanics.*

Lee, M.Y., B. K. Cook, A.A. DiGiovanni, E.D. Perkins, and J.R. Williams, "Simulation of Borehole Failure Phenomena Using Discrete Element Modeling", *Eos Trans. AGU*, 82(47), T51A-0846, 2001.

Well Integrity Assurance for Sub-Salt and Near-Salt Deepwater GoM Reservoirs

(BHP, BP Amoco, ChevronTexaco, Conoco, ExxonMobil, Halliburton, Kerr-McGee, Phillips, Shell, and SNL)

Highlight:

- Project results presented at a partners meeting in Houston, TX.

A draft report entitled, "Salt Mechanics Primer for Sub-Salt and Near-Salt Deepwater Gulf of Mexico Field Developments" by A. F. Fossum and J. T. Fredrich was distributed to the participants. The report is being issued as a Sandia National Laboratories report with distribution category Unlimited Release.

A manuscript entitled "Large-Scale Three-Dimensional Geomechanical Modeling of Reservoirs: Examples from California and the Deepwater Gulf of Mexico" by J. T. Fredrich and A. F. Fossum was submitted for consideration for publication in a special issue of the journal, Oil & Gas Science and Technology, based on a symposium convened at the Institut Français du Pétrole in December 2001.

A systematic series of non-linear finite element analyses using one of three idealized deepwater Gulf of Mexico (GoM) reservoir geometries were completed. The analyses focus on the evolution of the displacement and stress fields in a compacting disk-shaped reservoir located at depth below a horizontal-lying salt sheet.

A systematic series of non-linear finite element analyses of salt loading on well casings was conducted. A quantitative design tool was developed to predict closure for the case of circular through-salt boreholes. Additional analyses were conducted for elliptical (i.e., imperfect) borehole for a specific set of casing configurations. The latter analyses are significantly more complicated than the circular borehole analyses.

Project results were presented at a participants meeting in Houston, TX, held March 26. The meeting was attended by 13 individuals representing eight of the nine participating companies.

Drilling, Completion, and Stimulation Technology

Coiled Tubing Marking and Mark Recognition (Quality Tubing and INEEL)

Highlight:

- Project work concluded.

All technical work on this project concluded and the final report is being reviewed by technical editing. The final report should be printed and ready for distribution by May 1, if not earlier. This will be the final report on this project.

Drill Cuttings Injection Field Experiment (BP Amoco, ChevronTexaco, Exxon, Gas Research Institute (GRI), Halliburton Energy Services, Hughes Christensen, MSD, Pinnacle Technologies, Schlumberger, Shell, and SNL)

Highlight:

- Project closing out.

Project is in close-out phase with reporting and technology transfer under way.

3D Analysis for Induction Logging in Horizontal Wells (BP Amoco, ChevronTexaco, Conoco, Electromagnetic Instruments, Exxon, Halliburton, Mobil, Phillips, Schlumberger-Doll, Shell, Unocal, Western Atlas, and SNL)

Highlight:

- Progress made on the 1D anisotropic inversion scheme.

Great progress was made recently on the 1D anisotropic inversion scheme. The scheme employs simple upper and lower bounding constraints to stabilize the inversion process, with the bounds adjusted at each iteration to lie at plus or minus some percentage (say 10%) of the current parameter value. Global constraints are included so that a parameter will never be able to exceed geological reasonable values. These constraints enable the scheme to invert for vertical and horizontal conductivities, layer depths, and orientation of the well with respect to the tool. In addition, the Jacobian matrix is only calculated for parameters (conductivities and layer boundaries) that lie within a limited region around each tool position. This is much more efficient than computing the Jacobian matrix for all parameters along the well for each tool position. The end result of these modifications is that the scheme runs two to ten times faster than a previous version that employed a singular value decomposition (SVD) approach to stabilizing the inversion.

The scheme was tested on a number of models, and currently researchers are trying to secure accurate triaxial induction logging data for testing. One interesting note is that with coaxial data only, the solution for bed boundaries is extremely nonunique; bed boundaries must be fixed in order arrive at a solution. However, when the coplanar data are included with the coaxial, the inversion becomes extremely sensitive to bed boundary locations. Project researchers talked with people at Baker Atlas who currently have the only operating tool (EMI data is questionable), and they are still using routines that fix the bed boundaries. Thus, this may be the only project to date with a 1D anisotropic inversion that inverts not only for conductivity but layer thickness (at

least who are publicly admitting it).

In addition, numerical problems exist in the 1D forward code as written for very limited cases. Researchers are investigating methods to remedy these problems.

The progress on the GUI is also proceeding. The user is now able to input well-endpoints, sampling density, tool parameters, and a 1D anisotropic model, and the GUI will output a file that will allow for simulation of an induction logging tool along a well. To date only a 2C40 configuration was implemented. When the GUI is up and running for this simple case, researchers will build in a 6ff40 configuration, triaxial, and eventually, a user-specified configuration. Also, 3D visualization of the deviated well within the layered medium will be added in the near future.

Downhole Seismic Source for Look-Ahead Pore Pressure Prediction While Drilling

(Halliburton, INEEL, and LBNL)

Highlight:

- Test cell built and ready for tests.

A high-pressure test cell was designed and fabricated at the INEEL that will allow for capacitive-discharge seismic-source testing in the laboratory, simulating at-depth pressures. It consists of two adjustable gap electrical discharge electrodes and a high-frequency blast pressure sensor located in a small pressure vessel. The cell is capable of withstanding pressures up to 4,500 psi, thus simulating depths to 9,000 feet. The test cell will be placed in a tank of water with a hydrophone to evaluate first arrival acoustic amplitudes as a function of pressure. The blast pressure sensor will measure the test cell internal pressures during each shot. Testing will be performed with both a water-filled cell and a drilling-mud filled cell. The 200-J prototype CDDS laboratory source was modified to produce the capacitive discharge impulses. This test is scheduled for late April 2002.

Acoustic Telemetry (MWD)

(ABB, Electroacoustics Research Laboratory, Extreme, and SNL)

Highlight:

- Commercial interest in the acoustic telemetry tool is high.

Baker Oil Tools carried out another Canadian field test of the telemetry tool. Extreme Engineering and Baker Oil Tools are also planning to deploy the tool again later this month. Moreover, researchers are planning additional field deployments funded through a work-for-others contract with Schlumberger. The health of the commercial interest in this work is good.

The last component of the system, the radio-frequency surface receiver, is nearing completion. Next week researchers will be visiting Extreme Engineering to examine progress.

Development of Chemically Bonded Ceramic Borehole Sealants

(GPRI, ANL, and LANL)

Highlight:

- Bond between steel and sealant very high in both high and low temperature formations.

Project researchers identified the formulations for the borehole sealants for use in shallow and deep wells. The temperature and pressure range tested were 80°F to 300°F and 700 psi to 16,650 psi. These ranges include wells up to 20,000-ft deep (more than 99% of the wells). The formulation identified in this project can be used to provide a pumping time of at least 3–5 hours or longer if needed.

Researchers also tested the mechanical properties of the set sealants. The compressive strengths, measured on 2-in.diameter American Society for Testing Materials (ASTM) standard cylindrical specimens of deep well compositions that were set and cured in water at 170°F (a typical downhole temperature), cured in that same water for one day, and then dried in air at ambient temperature for two days gave a strength of 2049 psi.

Researchers measured the bond strength with downhole rocks (limestone and sandstone) provided by Exxon-Mobil. These rocks were cut in cylindrical

shapes. One end was flat and perpendicular to the length. The other end was cut at a 45° angle to the length. The specimens were put in plastic cylindrical molds of equal diameter and sealant slurry was poured over the slanted surface of the rocks. When the slurry set, it formed a complimentary solid cylindrical part attached to the slanted surface. The specimens were cured for three days and then taken out of the molds. The free end of the set sealant was cut into a flat surface perpendicular to the length, such that the entire specimen was now a cylinder with the rock, and the sealant bonded at the 45° surface. The shear bond strength was now measured using an Instron machine in a compressive mode. The shear bond strengths with limestone were more than 1931 psi for low temperature compositions and more than 4619 psi for high temperature compositions. At these values rocks crushed but the bonds were intact, so the actual shear bond strengths could not be measured. This implies that actual shear bond strength of the sealant with limestone is greater than the crushing strength of the rock itself. The shear bond strengths with sandstone were 4693 psi and 2492 psi, respectively, for low- and high-temperature formulations.

The shear bond strength with mild steel that represented a casing was also measured in a similar manner. Mild steel tubes of 2-in. length and 1.6-in. inner diameter were filled with the sealant slurry. Some samples were cured in air and some in water at 170°F. After curing for a day, they were left to cure for next three days so that those from water dried well. Then using a steel plunger of diameter equal to the ID of the steel mold, an attempt was made to force the set sealant out of the mold using the Instron machine in a compressive mode. The results between specimen to specimen varied widely. In all the cases, however, the specimens inside started crushing but the bond between steel and the specimen did not break. The highest force noted was 10,430-lb force. Since the force was reaching the limit of the load cell and entire machine started vibrating, the test was terminated. This implied that the actual bond strength was more than 1029 psi corresponding to the force of 10,430-lb force on the specific cylinder.

The results presented above indicate that the sealant has excellent bond strengths with rocks and steel. Researchers determined compositions that can be used to pump the sealant in more than 99% of the wells. The future study will be geared towards determining effects of saline water, drilling muds, and other conditions so that practical sealants can be identified.

Coiled-Tubing Deployed Microdrilling with Real-Time, Downhole Monitoring

(DeepLook, Phillips, and LANL)

Highlights:

- Procurements for improving the mud cleaning system completed.
- Proposal to drill, complete, and produce micro oil wells prepared.

A new, higher speed motor was procured for the mud cleaning system to power the feed pump for the hydrocyclone desanders. After it is mated to the feed pump, it will increase the output of the pump and fluid velocity through the hydrocyclones. This should increase the volume of fluid cleaned and the solids removed, as well as reduce the average particle size removed.

A procedure to accurately add and maintain the desired concentration of the low molecular weight polymer was outlined and the equipment needed to implement the procedure was designed. The polymer will be substituted for bentonite to determine if mud-cleaning performance can be improved.

Rocky Mountain Oilfield Technology Center (RMOTC)

A draft proposal was prepared and submitted to the RMOTC for their input. The proposal outlines a plan to conduct a microdrilling demonstration at Teapot Dome to drill, complete, and produce several 600-ft deep Shannon oil wells using the LANL coiled-tubing drill rig.

Microdrilling Motor

A 1-11/16-in. motor with lower flow requirements than the motors used to date, was identified and will be evaluated during the next drilling campaign. This motor should help, but not solve, the bore wall erosion observed in unconsolidated formations at the San Ysidro, NM, drill site.

Effects of Well Conditions on Post-Perforation Permeability

(Halliburton, Penn State, and LLNL)

Highlight:

- Commenced development of "early time" clean-up simulation capability.

Previous code development focused upon the movement of fines within the rock and the influence this has upon permeability and post-shot productivity. In addition to such later-time effects, the cleanup of damaged rock immediately adjacent to the perforation must be considered. To this end, the simulation capability is being enhanced to include inertial and transient gradient terms to investigate cleanup and removal of this heavily damaged rock.

Lifetime Performance Monitoring of Synthetic Fiber Mooring Ropes

(Petroleum Composites, Puget Sound Rope, Shell Global Solutions U.S.,Whitehill Manufacturing, and ORNL

Highlight:

- Integrated optical fiber-rope specimens are being made.

Representatives from Shell Global Solutions and Petroleum Composites met at ORNL in March to discuss plans for tensile testing of rope specimens with integrated optical fibers. Whitehill Manufacturing is in the process of making the integrated rope specimens, and the initial strain testing (i.e., correlating the applied strain to the measured strain) will be completed in the next reporting period.

Disposable Fiber Optic Telemetry System for Use With Coiled Tubing

(GTI, CTES, and SNL)

Highlight:

- The prototype fiber injector assembled satisfactorily and has undergone preliminary tests.

There is an increasing need for a high-data-rate, real-time, data link between downhole instrument packages and the surface. No current system adequately addresses this need, either because of low data rates (mud-pulse telemetry), interruptions to drilling (logging cable), or the need to substantially change the drilling process (various types of prewired pipe or composition coiled tubing with wiring built in).

In separate work, SNL and GTI are developing a system for using unarmored "bare" optical fiber as a disposable telemetry link. The advantages of this approach are that the bare optical fiber is so small and lightweight that the entire telemetry link can be placed directly into the drill string and deployed as needed during (without interfering with) the drilling process. Fiber optics can achieve megabit or higher data rates. This system was developed and tested for use in conventional drill pipe. Coiled tubing offers the opportunity to combine two existing technologies to provide a new level of telemetry to the industry: 1) cable injection, and 2) disposable optical fiber telemetry. CTES is an industry leader in cable injection technology for coiled tubing.

The purpose of the proposed work is to determine the applicability to coiled tubing of the disposable fiber optic telemetry technology developed for conventional drill pipe. There are two main technical issues: 1) injectability of the fiber using some modified form of current cable injectors and 2) survivability of the fiber under the mud flow conditions prevalent in coiled tubing.

A prototype fiber injector design was manufactured using the capstan-based injection system designed for injection of cable into coiled tubing pioneered by CTES. The modified injector addresses the challenge of injection of the much smaller and more delicate optical fibers. The unit assembled satisfactorily and

has undergone preliminary tests at CTES with promising results. The stiffness of the fiber optic cable, which initially complicated the injection step was, potentially addressed with the use of a 500um (0.5mm) fiber optic cable that is stiffer and apparently more durable.

Initial operational tests of the modified injector will be conducted in mid-April at the CTES location, monitored by an SNL representative.

Automatic Flaw Detection and Identification for Coiled Tubing (U of Tulsa, INEEL)

Highlight:

- Project completed.

This project is complete as of the end of March, on schedule, and on budget. The products of this project were a series of meetings with university and industrial-collaborators to develop a laboratory approach to collecting the data necessary to create software capable of real-time flaw classification and discrimination on coiled tubing. Three meetings were held with the University of Tulsa, and two with industry representatives. The final project plan was detailed in a Field Work Proposal to DOE-FE. FY02 funding was approved and is expected to arrive April 1. This will be the final report on this project.

Diagnostic and Imaging Technology

Advanced Sensor Technology for Microborehole and Other Seismic Instrumentation (Input/Output, Philips, and LANL)

Highlights:

- Designed circuit for wireline transmission of signals from miniature sensor.
- Sent circuit out for fabrication.
- Arrangements made to use another pre-commercial, proprietary sensor in testing at the San Ysidro, NM, site.

A 100-ft borehole was drilled five feet from the existing microhole to enable side-by-side comparisons of the multilevel microhole array with various conventional sensors. Initially, a geophone was packaged and installed in the borehole. Data were simultaneously collected from the Micro Electro Mechanical Systems (MEMS) microhole array and the geophone as a Bison accelerated weight drop source was moved along a seismic line. Good signal-to-noise was exhibited in both sets of data, with the MEMS array recording higher frequency seismic signals. The overall signal-to-noise in the geophone data exceeded that in the MEMS array data.

A circuit was designed for wireline transmission of signals from a pre-commercial, propriety miniature sensor. The circuit was sent out for fabrication. This sensor will be deployed in the 100-ft borehole, and tests comparing this sensor with the MEMS will also be conducted. Arrangements were made to gain access to yet another pre-commercial, proprietary sensor for testing at the San Ysidro, NM, site.

Large Downhole Seismic Sensor Arrays (ChevronTexaco, Conoco, Exxon, OYO Geospace, Shell, U of Arkansas, and INEEL)

No report received.

Improved Prestack Kirchhoff Migration for Complex Structures (Conoco, Cray/SGI, Golden Geophysical, Kerr-McGee, Shell, and LANL)

Highlight:

- Results of finite difference wave equation simulations compared with ray-tracing solutions.

Researchers continue to investigate how smoothing the velocity model influences the quality of image. Researchers are also looking at which portions of data contribute reliably to an image in complex media. The results of finite difference wave equation simulations are being compared with ray-tracing solutions for complex media to determine where rays are not reliably approximating significant features in the wavefield.

Inversion of Full Waveform Seismic Data for 3D Elastic Parameters

(Amerada Hess, ChevronTexaco, Conoco, Fairfield Industries, GX Technology, Marathon, Unocal, and SNL)

Highlights:

- Researchers study the extension of the method to solid anelastic media.
- Development of 3D acoustic wave algorithm continues.
- SEG expanded abstract being written.

Seismic waves propagating through realistic geologic media are attenuated and dispersed due to irreversible conversion of kinetic and strain energy to heat. However, the present full waveform inversion approach treats 3D elastic media, and does not accommodate anelastic losses. In order to understand how to incorporate attenuation into the inversion procedure, researchers initiated an examination of seismic wave propagation capabilities for 3D anelastic media.

A time-domain finite-difference algorithm, based on approximating an attenuative body as a standard linear solid, was implemented in a massively parallel computational environment at SNL. The numerical approach is computationally demanding, due to the introduction of numerous additional dependent variables (called memory variables) into the system of coupled partial differential equations that are solved. In order to comparatively assess demand for memory and execution time, a novel alternative algorithm for simulating wave propagation through a 3D anacoustic medium (i.e., an attenuative and dispersive fluid) was recently developed. Researchers refer to this approach as a finite integer-difference algorithm, since both a convolution integral and partial derivatives require numerical evaluation. Preliminary results indicate that the approach is accurate and computationally competitive, at least for anacoustic media. Extension of the method to solid anelastic media is being studied.

High-Speed 3D Hybrid Elastic Seismic Modeling

(Burlington Resources, GX Technology, and LBNL)

No report received.

Next-Generation Seismic Modeling and Imaging

(Advanced Data Solutions, Anadarko, BHP Petroleum, BP Amoco, ChevronTexaco, Conoco, Core Laboratories/Tomoseis, ExxonMobil, Fairfield Industries, Marathon, Mitchell Energy, Paradigm Geophysical, PGS-Tensor, Phillips, Shell, Society of Exploration Geophysicists [SEG], Unocal, Veritas DGC, Western Geophysical, Stanford, U of Houston, LANL, and LLNL)

Highlights:

- Negotiations continue with consortium for project use of their 3D model.
- Synthetic elastic data calculations continue in SEG/EAEG salt structure.

Negotiations continue with an industry consortium for use of their 3D salt model by the project. Significant topics discussed included generation of preliminary seismic data from the model, and the conditions under which the project-modified model can be released publicly.

Additional elastic data were calculated from the SEG/EAEG salt structure. The receiver geometry was modified to provide the denser spatial coverage that an industry participant needed to adequately test a processing method. All these data will be available via the project web site.

Rapid Imaging of Interwell Fluid Saturations using Seismic and Multiphase Production Data

BP Amoco, ChevronTexaco, JNOC, Landmark, Phillips, RC2, Statoil, Tomoseis, Total-Fina-Elf, Texas A&M, and LBNL)

Project researchers implemented a new approach to computing trajectories for use in the joint seismic-watercut inversion code. The methodology should work for general reservoir simulators, because it does not rely on quantities inherent to streamline simulators.In this approach researchers essentially post-processes the computed reservoir history from the simulator. Trajectories are computed using the computed reservoir history. The trajectories are an essential part of the sensitivity computations in the inversion.

Researchers utilized this approach in a prototype code for the inversion of seismic amplitude changes. A laboratory rock physics model and Gassmann equations are used to relate saturation and pressure changes to changes in seismic velocity and impedance. Researchers are in the process of testing the inversion code on a set of synthetic time-lapse seismic amplitude values.

The water-cut inversion code was generated to allow for gravity and compressibility. The code was tested on a million cell model from a field in the Middle East. Using the new version of the code, researchers are able to match reservoir history data from over forty wells.

Offshore Oil Field Characterization with EM Methods (SNL)

Highlight:

- New project for FY2002.

Project is awaiting funds before onset.

Innovative Wave-Equation Migration (Advanced Data Solutions, Amerada-Hess, Applied Geophysics Services, Baker Atlas, BHP, Conoco, Exxon-Mobil, Fairfield Industries, GX Technology, Petroleum GeoServices, Phillips, Screen Imaging, Shell, TomoSeis, Unocal, Veritas DGC, and LANL)

Highlight:

- Work begun on developing common-offset and common-angle wave-equation migration.

To study the velocity sensibility of the wave-equation migration methods, researchers performed migration velocity analysis for a synthetic dataset to obtain a velocity model. This procedure is similar to the realistic case where velocity is unknown and a velocity model is built using migration velocity analysis. Researchers compared migration results of the wave-equation migration with that of the ray-based Kirchhoff migration using the velocity model obtained by migration velocity analysis. To obtain a proper weight for a given image point for an amplitude-preserving migration, it is important to define the migration aperture for a given short-gather because of the limited aperture of seismic data; that is, for a given set of data, only a limited region is illuminated.

Researchers investigated an optimized approach using the wave path migration method to define the aperture. Researchers continue this work to use this aperture for wave-equation migration.

Researchers started working on developing common-offset and common-angle wave-equation migration.

Testing and Validation of High-Resolution Fluid Imaging In Real Time (Deeplook, KMS Technologies, KJT Enterprises, LBNL, and SNL)

No report received.

Autonomous Monitoring of Production (Aera Energy, ChevronTexaco, SteamTech Environmental Services, TomoSeis, and LLNL)

Highlight:

- Specialized data collection system being tested.

Work focused on developing the capability for operating unassisted, in automatic mode. Project researchers are pursuing parallel paths using a system originally designed for autonomous data collection and alternatively, using a software method to remotely activate the standard system, thus eliminating the requirement of a special piece of instrumentation.

The specialized data collection system is being tested in the laboratory. Operational control files were generated, and the complete hardware and software system was set up. The control software was loaded into the computers commonly used for data collection. Limitations were discovered in using the communications ports, and were resolved by the use of dedicated computers. These initial activities resulted in a successful test of the entire system working

in the local mode—that is, controlled only by the computer in the field (currently performed manually). A hardware problem was discovered in the transmitter (power source) and was sent to the manufacturer for repair.

Project researchers are also pursuing an approach in which the standard field system collects data autonomously using software-controlled access from a remote computer. Commercially available control software is being installed, and system testing is scheduled to begin in the next few weeks.

Initial interpretation of field results obtained in the Vacuum field continues, with input from the production engineers.